10/538139
JC12 Rec'd PCT/PTC 09 JUN 2005

5/PRTS

INTEGRATED OPTICS COUPLING ELEMENT ~~COMPRISING A GRATING~~ CREATED IN A ~~CLADDING AND~~ ITS FABRICATION ~~METHOD~~

TECHNICAL FIELD

The invention relates to an integrated optics coupling element comprising an optical grating created in a cladding as well as its fabrication method.

The invention has applications in all fields requiring a coupling between an optical cladding and a guide core or vice versa and in particular in the field of spectral filtering. It particularly applies to the creation of gain flatteners for optical amplifiers used for example in the telecommunications field or even for creating linear response filters whose wave length is on a spectral band defined for the spectral recognition in particular for the measurement of spectral offsets from a power variation for example in the field of sensors.

STATE OF THE PRIOR ART

Currently, the creation of grating coupling elements in optical fibre claddings is known. In this field, the optical cladding of a fibre traditionally surrounds the fibre core has a refractive index lower than that of the core to allow the propagation of a light wave in the core. Conjointly, the optical cladding permits the mechanical support of the core. The fibre core cannot exist without the cladding.

Furthermore, the grating created in the fibre permits one or more guided modes to be coupled in the

core of a fibre to one or more fibre cladding modes or vice versa.

The document (1) whose reference is provided at the end of the description illustrates a grating coupling element obtained by etching the cladding. However, the creation principle of this type of grating is complex, among others it requires the cladding to be etched, which makes the fibre fragile.

Figure 1 shows a perspective view of an example of a coupling element in an optical fibre. The fibre 1 comprises a core 3 (shown in dotted lines) and a cladding 5; the latter has been etched for a period Λ to create a grating R. We can clearly see in this figure that the mechanical rigidity of the fibre is modified by the etching 7 created in the cladding 5.

In addition to the mechanical difficulties, as the core of a fibre cannot exist without the optical cladding, this dependence restricts the possibilities of modifying the parameters of the cladding, gratings and solutions for the design, architecture and integration of the coupling elements in complex systems.

DESCRIPTION OF THE INVENTION

The purpose of this invention is to propose an integrated optics coupling element comprising an optical grating created in a cladding by modulation of the cladding structure as well as its creation process. The use of an integrated optics cladding permits the difficulties of the prior art to be overcome by offering in particular more flexibility in the

fabrication of the modulation of the cladding structure and by offering an element that is not fragile.

One purpose of the invention is also to propose a coupling element comprising a grating included in a cladding that is independent of the guide core to which it is associated. By independence of the core and the cladding, it is meant that can exist in a substrate independently from one another. In other words, the core can exist without the cladding and the cladding can exist without the core.

More precisely, the integrated optics coupling element of the invention comprises in a substrate an optical guide core, an optical cladding independent of the core and surrounding at least one portion of the core in a zone of the substrate called the zone of interaction, in which the cladding has at least in the zone of interaction a modulation of its structure so as to form a coupling grating between the guide core and the optical cladding, in which the refractive index of the cladding is different from the refractive index of the substrate and lower than the refractive index of the core, at least in the part of the cladding next to the core in the zone of interaction.

By surrounding, it is meant that the fundamental mode profile of the guide core has a maximum that is included in the index profile of the cladding. In this way, the fundamental mode profile of the core may be completely or partially included in the cladding index profile, which results at structural level in a core positioned anywhere at all in the cladding including at

its edge in which case the core may be partially outside of the cladding.

The zone of interaction corresponding to a grating coupling zone in a substrate will also be called "artificial cladding grating" (ACG). In fact, in this zone, the cladding is artificially created in the substrate and independently of the core.

The grating formed from the cladding is capable of coupling the one or more core modes to one or more cladding modes or vice versa.

In a first advantageous embodiment, the modulation of the cladding structure is a modulation of its section and preferably of its width, considered in a direction perpendicular to the direction of propagation of the modes.

In a second advantageous embodiment, which may be combined with the first mode, the modulation of the cladding structure is a modulation of the position of the cladding with respect to the core.

The fabrication of the integrated optics cladding permits it to be obtained by a modification of the refractive index of the substrate, in particular by implantation or ionic exchange. Consequently, the modulation of the cladding structure can be obtained without etching or fusion as in the prior art.

The solution of the invention therefore offers advantages such as the simplicity of creation and sturdiness of the coupling element.

Furthermore, the independence between the core and the cladding allows a higher number of combinations to be created by varying not just the size of the cladding

but also the position of the core in the cladding. The independence of the cladding and the core also permits easy integration of the coupling element of the invention into a complex architecture.

The grating of the invention may comprise one or more elementary gratings, each elementary grating creating an elementary zone of interaction.

The effective index n^0_{eff} of the mode spreading in the core depends on the surrounding medium. According to the cladding index and its extent in the substrate, the value of the effective index of the core mode changes. In this way, by periodically or pseudo-periodically modulating the cladding structure, this variation can be transmitted to the effective index value of the core and thus induce a coupling between the one or more core modes and the one or more cladding modes and in this way create a grating.

The use of the modulation of the cladding structure is particularly advantageous to create a grating. In fact, one of the factors restricting the parameter adjustment of the coupling coefficient desired for the grating is provided, in the case of masks being used, by the size of the minimum pattern of the mask lithography permitting the gratings to be created. As this limit is identical for the core and the cladding, it can be easily understood that it is easier to obtain slight variations on n^0_{eff} by varying the structure of the cladding. Consequently, grating type component applications, in particular apodised, are thus favoured.

In a first embodiment, the grating formed by the modulation of the cladding structure is an apodised grating.

In a second embodiment, the grating formed by the modulation of the cladding structure is a chirped grating.

As we have already seen, the cladding structure has an influence on the effective index of the core mode. Whereas the value of the resonance wave length of the ACG for a coupling from the 0 mode of the core to the j mode of the cladding depends on the effective index values as shown by the following equation:

$$\lambda_{0j} = \Lambda \text{ x } \left(n_{eff}^{0} - n_{eff}^{j} \right) \qquad (1)$$

Λ is the period of the grating.

A variation in the size of the cladding and/or de its position with respect to the core therefore permits the value of λ_{0j} to be accorded.

Coupling the core for example to the cladding (the same logic can be used for coupling the cladding to the core), results in a transfer of energy between the guided mode of the core and that of the cladding for wave lengths of λ_{0j}. The energy coupled in the cladding modes is then guided in the cladding generally with losses.

The modification of λ_{0j} therefore passes by adjustment of the parameters of Λ and/or the distribution of the effective indices of the various modes.

The efficiency of the coupling between the modes depends on the length of the grating and the coupling coefficient K_{0J} between the 0 and j modes. This coefficient is provided by the spatial recovery integral of the 0 and j modes, weighted by the index profile induced by the grating. We therefore have a relationship of the type:

$$K_{OJ} \propto \iint \xi_0 . \xi_j^* . \Delta n . ds \quad (2)$$

where:

– ξ_0 and ξ_j are the transversal profiles of the 0 and j modes and ξ_j^* is the complex conjugate of ξ_j

– Δn is the amplitude of the effective index modulation induced by the grating in a plane perpendicular to the direction of propagation of the wave,

– ds is an integration element in a plane perpendicular to the axis of propagation of the wave.

The modification of K_{0j} is obtained by varying the profile of the modes and/or the index profile induced by the grating, in other words by varying the opto-geometrical characteristics of the cladding and/or of the core (dimensions, index level, etc.) and/or the characteristics of the grating (Δn, position of the grating with respect to the core and to the cladding, etc.).

As concerns a cladding, the larger its dimensions and index level, the more cladding modes will be allowed to spread and the more spectral filtering bands

will be possible. This may be an advantage if seeking multiple filtering or to have more flexibility in the selection of a filtering mode.

If seeking to limit the number de cladding modes that can be coupled, it is of interest on the contrary to reduce the opto-geometrical dimensions of the cladding.

As concerns the core, its dimensions and index level determine the characteristics of the mode, which spreads. Furthermore, the more the index differences between the core, the cladding and the substrate are high, the more there will be potentially a chance of having couplings for low grating periods as shown by the equation (1) (at a wave length of given resonance, the period is inversely related to the index difference between the guided mode of the core and the cladding mode).

By modifying the position of the core, the grating and the cladding, different couplings can be generated. In fact, we can clearly see from the equation (2) that the coupling force depends on the relative position in the plane transversal to the axis of propagation of the profiles of the cladding mode, of the guided mode of the core and the grating.

In particular, from the equation (2), it can easily be shown that a decentration δx of the core with respect to the cladding permits K to be increased.

Also, in one embodiment of the invention the core of the coupling element is totally or partially decentred with respect to the cladding.

By spectral band it is meant a band with a set of wave lengths whose central wave length and band width are determined, given that a light wave can comprise one or more several spectral bands.

In the invention, the cladding and the core exist independently from one another in the substrate, which is not the case in the prior art. This independence permits more flexibility in the creation of the coupling element. In particular, the core can no longer be situated in the cladding outside of the zone of interaction but solely in the substrate which permits the optical isolation of the core. In this way the cladding only influences the propagation of a light wave in the associated guide core in the part surrounding the core and the cladding can guide or transport light waves independently of the core.

The substrate may of course be made using a single material or by the superposition of several layers of materials. In this case, the refractive index of the cladding is different from the refractive index of the substrate at least in the layers next to the cladding.

Advantageously, each elementary cladding has a refractive index higher than that of the substrate.

In the invention, the guide may be a planar guide when the light is confined in a plane containing the direction of propagation of the light or a micro guide, when the light is confined in two directions transversal to the direction of propagation of the light.

The grating may be formed by an elementary grating or a set of elementary gratings in series. The

characteristics of the zone of interaction of the coupling element are such that they permit the desired light spectrum to be obtained at the output of this element.

In one preferred embodiment, the cladding and/or the guide core, may be created by any type of technique which permits the refractive index of the substrate to be modified. In particular we can mention the ion exchange techniques, ionic implantation and/or radiation for example by laser exposure or laser photo inscription or even the depositing of layers.

The technology of ion exchange in glass is particularly interesting but other substrates apart from glass may of course be used such as for example crystalline substrates of the KTP, $LiNbO_3$ or even the $LiTaO_3$ type.

When the cladding is created from a mask, the grating pattern is advantageously obtained by the same mask.

The invention also relates to a method for fabricating an integrated optics coupling element as previously defined, the cladding and the guide core being respectively created by modification of the refractive index of the substrate so that at least part of the cladding next to the core and at least in the zone of interaction, the refractive index of the cladding is different from the refractive index of the substrate and lower than the refractive index of the core and so that the cladding in the zone of interaction comprises a modulation of its structure capable of forming the grating.

In one preferred embodiment, the method of the invention comprises the following steps:

- a) introduction of a first ionic species in the substrate to permit the optical cladding to be obtained after step c),

- b) introduction of a second ionic species in the substrate to permit the guide core to be obtained after step c),

- c) burying of the ions introduced in steps a) and b) to obtain the cladding and the guide core,

The order of the steps may of course be inverted.

The first and/or the second ionic species is/are advantageously introduced by an ionic exchange, or by ionic implantation.

The first and second ionic species may be the same or different.

The introduction of the first ionic species and/or the second ionic species may be made with the application of an electrical field.

In the case of an ionic exchange, the substrate must contain ionic species capable of being exchanged.

According to one preferred embodiment, the substrate is made of glass and contains Na^+ ions introduced beforehand, the first and second ionic species are Ag^+ and/or K^+ ions.

In a first embodiment, step a) comprises the creation of a first mask comprising a pattern capable of creating the cladding, the first ionic species being introduced through this first mask and step b) comprises the elimination of the first mask and the creation of a second mask comprising a pattern capable

of creating the core, the second ionic species being introduced through this second mask.

The first mask comprises a pattern whose structure is modulated to obtain the desired structure modulation of the cladding permitting the grating to be formed.

In one variant of the embodiment, the first mask comprises a uniform pattern, in which the modulation of the cladding structure is obtained after elimination of the first mask by localised heating of the cladding, by any known means.

In a second embodiment, step a) comprises the creation of a mask comprising a pattern capable of creating the cladding and the core, the introduction of the first and the second ionic species of steps a) and b) being carried out through this mask; the modulation of the cladding structure is advantageously obtained in this case by localised heating.

The masks used in the invention are for example made of aluminium, chrome, alumina or dielectric material.

In a first embodiment of step c), the first ionic species is buried at least partially prior to step b) and the second ionic species is buried at least partially after step b).

According to a second embodiment of step c), the first ionic species and the second ionic species are buried simultaneously after step b).

According to a third embodiment of step c), the burying comprises the depositing of at least one layer of refractive material, whose index is advantageously

lower than that of the cladding, on the surface of the substrate.

This mode may of course be combined with the two previous modes.

Advantageously, at least part of the burying is carried out with the application of an electrical field.

Generally prior to burying with an electrical field and/or the depositing of a layer, the process of the invention may comprise among others burying by re-diffusion in an ionic bath.

This step of re-diffusion may be carried out partially prior to step b) to re-diffuse the ions of the first ionic species and partially after step b) to re-diffuse the ions of the first and second ionic species. This re-diffusion step may also be carried out completely after step b) to re-diffuse the ions of the first and second ionic species.

By way of example, this re-diffusion is obtained by plunging the substrate in a bath containing the same ionic species as that previously contained in the substrate.

Other characteristics and advantages of the invention will become clearer from the following description, In reference to the figures of the appended drawings. This description is given by way of illustration and is not restrictive.

BRIEF DESCRIPTION OF THE FIGURES

- Figure 1 already described, shows diagrammatically an optical fibre comprising a grating created by etched grooves in the cladding,

- figure 2 shows diagrammatically in cross section, a first example of an embodiment of a coupling element of the invention,

- figure 3 shows diagrammatically in cross section, a variant of the embodiment of the coupling element of figure 2,

- figure 4 shows diagrammatically in cross section, a second example of an embodiment of a coupling element of the invention,

- figure 5 shows diagrammatically in cross section, a third example of an embodiment of a coupling element of the invention,

- figure 6 shows diagrammatically in cross section, a fourth example of an embodiment of a coupling element of the invention,

- figure 7 shows diagrammatically in cross section, an example of an application of the coupling element of the invention,

- figures 8a to 8d show diagrammatically an example of an embodiment of the invention,

- figures 9a and 9b show diagrammatically a variant of an embodiment of the invention, and

- figures 10a and 10b show diagrammatically examples of embodiments of the mask permitting a cladding with section modulation to be obtained.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

Figures 2 to 7 show examples of embodiments of coupling elements in cross sections containing the direction of propagation x of the light waves in the core of the said element. In order to simplify things, the direction of propagation is shown contained in a same plane, it of course being understood that the element core may be buried at variable depths.

Figure 2 shows diagrammatically in cross section, a first example of an embodiment of a coupling element of the invention.

This figure shows a substrate 11 in which a cladding 13 and a core 12 are created. The cladding 13 comprises a modulation of its width (considered in a direction y perpendicular to the direction of propagation x) in a zone I of the cladding, called the zone of interaction. This width modulation creates a grating R with a pitch Λ capable of coupling one or more core propagation modes to one or more cladding propagation modes or vice versa.

The core exists independently of the cladding. It has a constant section and in this example traverses the cladding and in particular the zone of interaction I.

In this example, the cladding has a section which varies sinusoidally with the pitch Λ. To simplify this figure, only four grating periods have been shown.

Figure 3 shows diagrammatically in cross section, a variant of an embodiment of the coupling element of figure 2. This element differs from that of figure 2 by a core 14 which is decentred with respect to the axis

of symmetry of the cladding in the direction x. This variant permits a parameter element to be added concerning the coupling coefficient between the cladding and the core by the grating.

Figure 4 shows diagrammatically in cross section, a second example of an embodiment of a coupling element of the invention.

As in figure 2, this coupling element comprises in a substrate 11, a core 12 which traverses the cladding 15 in its axis of symmetry considered in the direction x.

The cladding also has a modulation of section, creating a grating R. In this example, the grating is an apodised grating. In fact, the pseudo-sinusoidal pattern of the grating is not constant decreases at both ends. This is the principle of apodisation that means that the disruption which generates the coupling phenomenon in the zone of interaction I appears and progressively disappears along the propagation of the one or more modes.

The variation of section of the cladding induces disruptions whose consequences may be much less important than in the case of the variation of the core section (in particular due to the dimensions of the cladding). The modulation of the section of the cladding of the invention thus makes apodisation easier.

Other artificial cladding gratings may be created from a variation of the cladding structure. By way of example, figure 5 shows a chirped type grating for which the pitch of the section modulation of the

cladding 17 evolves. The other elements of this figure are the same as those of figure 4 and have the same references.

It is also possible to combine the different examples of embodiments of the coupling element of the invention and create for example a grating that is both chirped and apodised.

It is difficult to create apodised or chirped gratings by etching, especially for apodisation which requires good control, distributed along the length of the grating, from the cladding variation. The use of gratings created according to the invention is particularly advantageous.

Figure 6 shows diagrammatically in cross section a coupling element of the invention in which the modulation of the cladding structure is created by modulation of the position of the cladding with respect to the core.

Consequently, we can see on this figure the substrate 11 in which a cladding 18 is created that is traversed by the core 12.

In this example, the section of the cladding is constant but its position in the cross section plane of the figure follows with respect to the axis x, a sinusoidal function of period Λ.

Of course, these different variants of the invention may be combined with one another.

The fabrication of the grating of the invention by modulation of the cladding structure permits a core with a constant section to be created. This point is of particular interest when the coupling element is

integrated into a more complex architecture. In this case in fact, the coupling element is associated to the rest of the component by creating simply the cladding in a zone of the substrate comprising the core, which permits the operation of the component to be checked without the artificial cladding grating without having to make another mask for the part of the core that is to be associated to the zone of interaction.

By way of example, figure 7 shows a coupling element that is in fact integrated into an optical architecture, in this example the architecture is an integrated optics coupler in a substrate 21.

In this way, the coupler comprises in the substrate 21, two guide cores 24 and 25 which are close to one another in a coupling zone 26 in order to permit an energy exchange from one of the guides to the other and vice versa. The core 24 is associated among others after the coupling zone to a coupling element 30 of the invention. This coupling element is formed for example by a cladding 31 comprising a modulation of its section and by the part of the core 24 which traverses the cladding.

Thus, when a light wave penetrates the core 24 by one end 22, it is first of all split in the coupling zone into two parts, one part of the wave continues to be transported by the guide 24 whilst the other part is transported by the core 25. The part of the wave transported by the core 24 is filtered by the coupling element 30 before leaving by the end 28 of the guide. The end 27 of the coupler directly transmits the part of the wave coupled by the coupling zone in the core

25. We consequently obtain at the output, a filtered signal and a reference signal.

One application of the component of figure 7 may be for example a spectral detection system. In fact, if the coupling element 30 has a wave length linear response, the end 28 of the core 24 can provide a signal that depends on the wave length, whereas the end 27 provides a standardisation signal permitting the spectral characterisation for example of the position of a fine emission ray in the analysis spectrum.

This coupler may be advantageously optimised, before the coupling element 30 is created; this is especially advantageous for balancing the two output ends 27 and 28.

Figures 8a to 8d show diagrammatically an example of an embodiment of a coupling element of the invention (for example that of figure 2) using ion exchange technology and masks.

These figures are cross sections in a plane perpendicular to the surface of the substrate and perpendicular to the direction x of propagation.

Figure 8a shows the substrate 11 containing B ions.

A first mask 61 is created for example by photolithography on one of the faces of the substrate; this mask comprises an opening determined according to the dimensions (width, length) and the pattern of the cladding 13 that we wish to obtain. The mask 61 thus comprises the same modulations as those that we wish to create in the cladding.

A first ionic exchange is therefore created between the A ions and the B ions contained in the substrate, in a zone of the substrate situated next to the opening of the mask 61. This exchange is obtained for example by soaking the substrate equipped with the mask in a bath containing A ions and by possibly applying an electrical field between the face of the substrate on which the mask is located and the opposite face. The zone of the substrate in which this ionic exchange takes place forms the cladding 13.

To bury this cladding, an A ion re-diffusion step is carried out with or without the use of an electrical field applied as previously described.

Figure 8b, shows the cladding after it has been partially buried. The mask 61 is generally removed before this step.

The creation of the cladding of the invention is therefore similar to the creation of a guide core but with different dimensions.

The following step shown in figure 8c consists of forming a new mask 65 on the substrate for example by photolithography after possibly cleaning the face of the substrate on which it is created. This mask comprises patterns capable of permitting the creation of the core 12.

A second ionic exchange is then created between the B ions of the substrate and the C ions which may or may not be the same as the A ions. This ionic exchange may take place as previously described by soaking the substrate in a bath containing C ions and by possibly applying an electrical field.

Finally, figure 8d shows the component obtained after burying the core 12 obtained by re-diffusion of the C ions and final burying of the cladding, with the use or not of an electrical field. The mask 65 is generally removed before this burying step.

The conditions of the first and second ionic exchanges are defined in order to obtain the differences of refractive indices desired between the substrate, the cladding and the core. The adjustment parameters of these differences are in particular the exchange time, the temperature of the bath, the concentration in ions of the bath and the presence or absence of an electrical field.

As an example of an embodiment, the substrate 11 is made of glass containing Na^+ ions, the mask 61 is made of aluminium and has an opening of around 30 µm wide and a modulation on the opening of between a few and several dozen micrometers (the length of the opening depends on the desired length of the cladding for the application in question).

The first ionic exchange is carried out with a bath comprising Ag^+ ions at around 20% concentration, at a temperature of around 330°C and for an exchange time of around 5 min. The cladding thus formed in the glass is then partially buried. This burying step is carried out by re-diffusion in a sodium bath at a temperature of around 260°C. The length of this step depends on the depth of burying desired for the final component. In this way, for a surface component a duration of around 3 minutes is sufficient whereas for a buried component a duration of around 20 minutes will

be selected. In this second case, it is also necessary to carry out the burying of the cladding under an electrical field before the second exchange. In this way, a current of 20 mA is applied between two sodium baths on either side of the plate at a temperature of 260°C for 10 minutes.

The mask 65 is also made of aluminium and has a pattern opening of around 3 µm wide (the length of the pattern depends on the desired length of the core for the application in question).

The second ionic exchange is carried out with a bath also comprising Ag+ ions at around 20% concentration, at a temperature of around 330°C and for an exchange time of around 5 min. Then the core thus formed is partially buried in the glass by re-diffusion in a sodium bath at a temperature of around 260°C for 3 min. For a buried component, this step is not necessary.

The final burying of the cladding and the core takes place under an electrical field, with the two opposite faces of the substrate in contact with two baths (in this example sodium) capable of permitting a difference in potential to be applied between these two baths. For a surface component, a duration of less than one minute is sufficient, in the case of a buried component a duration of around 30 minutes is used, with the burying being carried out with a current of 20 mA at 240°C.

Many variants of the previously described process may be created. In particular, the burying steps of the cladding and the core may be carried out as previously

described during 2 successive steps but they may also be carried out simultaneously in certain cases, with the core having an ionic concentration higher than that of the cladding, it is buried quicker than the cladding, which permits among others to centre the core in the cladding.

The difference in concentration between the core and the cladding is generally obtained either by re-diffusion in a bath of ions forming the cladding or by a difference in concentration of the ions introduced in steps a) and b).

As we have already seen, to bury the cladding and the core, a variant of the process consists of depositing on the substrate 11, a layer of material 68, shown in dotted lines in figure 8d. In order to make optical guiding possible, this material must advantageously have a refractive index lower than that of the cladding.

Moreover, in this example the cladding is created before the core but it is of course possible to create the core before the cladding.

The fabrication of the component of the invention is not restricted to the technique of ion exchange. The component of the invention may also be created by any techniques which permit the refractive index of the substrate to be modified.

Furthermore, as we have already seen, the period, size and position of the grating created, with respect to the core and the cladding, are parameters which can be adapted to suit the applications.

Figures 9a and 9b show in a perspective view a variant of an embodiment of a coupling element of the invention that does not use masks.

Thus figure 9a shows the substrate 11 in which a cladding 60 with a uniform structure has been created beforehand, for example by masking and ion exchange. Localised heating 63 of the cladding is then created by means of a laser beam 71 (for example a CO_2 type laser) aimed at the substrate. This beam is moved along the cladding, by intervals corresponding to the desired period of the grating. The localised heating produces re-diffusion of the ions in the cladding, which results in both a change in section and index. The grating R is thus created in the cladding.

After this step (figure 9b), a guide 75 is fabricated in the cladding for example also by masking and ion exchange in order to obtain the coupling element of the invention.

In this example of the embodiment, the modulations of the cladding structure are obtained without modulating the cladding mask pattern. It is therefore possible to modify the opto-geometrical distribution of the cladding by simply creating periodic or pseudo-periodic localised heating. This heating can be obtained by all means permitting part of the substrate to be heated locally on a zone around the size of the desired grating period, following the direction of propagation of the modes. The se means may be for example laser exposure or the use of an electrical arc.

The exposure of the cladding to a laser beam may also be made after the guide core has been created.

Figures 10a and 10b show diagrammatically examples of embodiments of the masks M1 and M2 permitting a cladding with section modulation to be obtained.

These figures are elevation views of the masks and only show the part of the masks permitting the grating to be obtained. The white zones of the mask patterns correspond to the openings of the masks.

These masks permit a periodic grating of period Λ to be obtained by variation of the width of the patterns.

REFERENCE

- [1]: C.Y. Lin and L.A. Wang, "Loss-tunable long period fibre grating made from etched corrugation structure", Electron. Lett., 35 (21), (1999), pp 1872–1873